RESEARCH STUDIES OF STELLAR CHROMOSPHERES AND CORONAS

Final Technical Report,

covering the period

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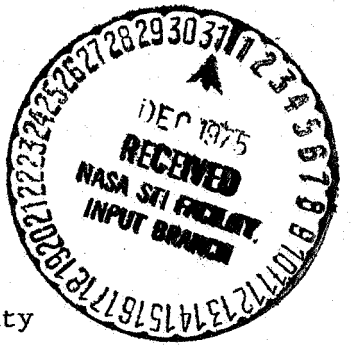

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ABSTRACT

Ultraviolet Observations of late-type stars from OAO-3 Copernicus were designed and carried out. Discoveries and detections of chromospheres, coronas, and stellar winds as inferred from measured emission lines were made, and analysis and interpretation of the data are continuing.

INTRODUCTION

Although the investigation of late-type stars was not one of the original research goals of the Princeton experiment on Copernicus, it has turned out to be a scientifically important and rewarding area of study. Extrapolating from the Sun, we expect to find chromospheres and coronas on other late-type stars, although they would have different atmospheric structure and possibly different dynamics. Emission lines from chromospheres and coronas have been detected from several stars that span a range of excitation conditions and represent temperatures from 7000 ^{o}K to ~ 500,000 ^{o}K. Additionally, evidence for expanding atmospheres has been found. Eventually, mass loss will occur that relates intimately to the evolution of stars.

Several areas of interest covered by this Grant are discussed below. They are stellar chromospheres and coronas, dynamics of late-type stellar atmospheres, and the local interstellar medium.

STELLAR CHROMOSPHERES AND CORONAS

Data have been acquired from a number of stars of spectral type G, that cover a range of luminosity classes. Single and binary systems are included as well. While many of these observations have not been fully reduced, in several cases, atmospheric models have been constructed.

Emission lines of Mg II, H Lyman α, C II, Si III, N V and O VI have been detected in one or more sources. Attempts to find more highly excited species, namely Fe XII and Fe XIX were unsuccessful. The coronal temperatures of two stars α Aqr and α Aur have been found to be ~ 4×10^4 ^oK and ~ 5×10^5 ^oK respectively. The star α Aur has turned out to be particularly interesting because it is a variable source of soft X-rays that appear to originate in active regions on the primary star.

DYNAMICS

A result of the ultraviolet observations is the detection of expansion in the atmospheres of late-type stars. This is surprising since there is no spectroscopic evidence of such an expansion in the Sun. The resonance lines of Mg II and Lyman-α in many of these stars show the typical asymmetry-enhanced red emission peak and blue shifted central absorption-that is expected in a differentially expanding atmosphere. As stars of later spectral type are encountered, the differential expansion occurs at lower temperatures in the stellar atmosphere. Additionally, lines of higher excitation, C II and O VI for instance are displaced toward the blue, implying an outward expansion of the atmosphere. Here we have evidence for expansion that can lead to mass loss. The mass loss that occurs is difficult to determine without additional observations or theoretical constraints on the problem. We are attempting further observations of α Aur in 1976 to measure line intensities that can be used as plasma diagnostics for electron densities.

LOCAL INTERSTELLAR MEDIUM

Late-type stars show emission in the Lyman-α line of hydrogen that is partially absorbed by the neutral hydrogen along the line-of-sight to the star. Since these stars are nearby, they offer a unique way to determine the density of the hydrogen in the local solar neighborhood. Early-type stars, which are widely used for hydrogen density determinations lie at a distance from the Sun ~ 100 pc or greater. By contrast, the late-type stars are within ~ 50 pc of the Sun. The two stars we have used to investigate the density are unique in their way. One, α Aur has a Lyman-α line with the highest photon flux to be observed with Copernicus. thus giving a good signal-to-noise ratio. The other star is α Cen A that is a solar-type star (G2V) in which the intrinsic profile of Lyman-α is the best known. Both of these stars indicate relatively low densities of interstellar hydrogen- $n_H \lesssim 0.02$ atoms cm^{-3}. Such low densities suggest that the solar neighborhood is a local low density region. Possibly, we may be in a local low density "tunnel", part of a "fossil Stromgren sphere" from a supernova remnant, or indeed at the edge of the Gum Nebula.

Low column densities of neutral hydrogen also imply that radiation below 900 Å can penetrate the interstellar medium without as much attenuation as previously thought. Such a result opens up new ranges in the electromagnetic spectrum to the astrophysicist and allows close investigation of additional phenomena in the stellar and interstellar populations.

FUTURE WORK

This Grant will be continued with A. K. Dupree as Principal Investigator. Additional observations will be taken with the Princeton Experiment on Copernicus; modeling and analysis of the atmospheres will continue. Collaborative programs with J. Lester and T. Ayres of the Center for Astrophysics will utilize the Ca II H and K lines to fully model chromospheres and study the dynamics of atmospheres.

AMERICAN ASTRONOMICAL SOCIETY
Abstract submitted for the 147th meeting
Category 7, Date submitted 7 October 1975
Read by H. Shipman

Measurement of the Interstellar Hydrogen Density towards α Centauri. A. K. DUPREE, Center for Astrophysics, and H. L. SHIPMAN, U. of Delaware. — The profile of the Lyman-α line has been measured in the nearby star α Centauri A (G2 V) with the Princeton Experiment Package on the Copernicus (OAO-3) satellite. Wavelength scans have been obtained with both high (~0.05 Å) and low (~0.18 Å) resolution. The intensity in the self-reversed core of Lyman-α is not zero, in fact the profile is remarkably similar to that of the Sun. Such a similarity implies a low value of the column density of neutral hydrogen to α Cen. Preliminary upper limits suggest $N_H \leq 10^{17}$ cm^{-2} and $n_H \leq 0.03$ cm^{-3} for a stellar distance of 1.3 pc. This result is in harmony with other recent measurements from nearby late type stars and suggests that the solar neighborhood may be a low density region. Other features of these scans will be discussed.

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AMERICAN ASTRONOMICAL SOCIETY
Abstract submitted for the 147 meeting
Category 5 - Date submitted 7 October 1975
Read by A. K. Dupree

The Chromosphere and Corona of Capella.

A. K. DUPREE and S. BALIUNAS, Center for Astrophysics, Harvard and Smithsonian Obs. - A model is constructed for the upper chromosphere and corona of the primary star (G5 III) of the α Aurigae system. This model is based on ultraviolet observations obtained with the Princeton Experiment Package on the OAO-3 satellite Copernicus. Multiple observations of the Lyman-α and O VI (λ 1032 Å) transitions suggest that the emissions can be associated with the primary star. Additional emission lines that are incorporated into the model cover a range of excitation from Mg II (2795 Å, 2803 Å) formed in the chromosphere, to the transition region and coronal lines of Si III (1206 Å), N V (1238 Å, 1242 Å) and O VI (1038 Å). Expansion of the atmosphere is present, setting in at the level of Lyman-α formation and continuing through the region where O VI is found. The resulting atmospheric models, energy balance, and dynamics will be compared with theoretical predictions.

This research is supported in part by NASA Grant NGR 22-007-285 and NASA Contract NAS 7-100.

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